PRELIMINARY DRAFT

SUMMARY OF RESULTS FROM GROUNDWATER TRACING INVESTIGATIONS AT ELECTRIC LAKE, UTAH.

Introduction

This report provides a preliminary draft summary of results from groundwater tracing investigations at Electric Lake. Various draft and interim documents related to the tracing work and the performance of the tracer dyes in the local geologic environment have previously been prepared. Some of these previous documents are included with the present document as appendixes. The present draft document summarizes previous reports and, where needed, updates or expands upon the previously presented information. While we are confident of the fundamental findings and conclusions, final analytical data verification has not been completed and the data presented must still be viewed as preliminary and subject to revision. We hope that the reader will find this a useful and efficient presentation of interim information on this important investigation.

This report deals with three principal investigations:

- A groundwater tracing study following two April 1, 2003 dye introduction into the bottom of Electric Lake over mapped faults.
- A bench test to assess the magnitude of dye losses onto samples of local bedrock.
- A groundwater tracing study following two February 24, 2004 dye introduction into the bottom of Electric Lake at approximately the same locations used during the April 1, 2003 dye introductions.

Groundwater Tracing Methods

Groundwater tracing with fluorescent tracer dyes is an effective way of determining hydrologic connections in groundwater systems. The tracer dyes are especially useful in groundwater systems where there are preferential flow routes such as fracture zones. Two of the dyes most commonly use in groundwater tracing studies, and those used in these studies, are fluorescein and eosine. Aley (2002) provides substantial information on properties of these dyes and their use in groundwater tracing investigations.

Fluorescein dye (also known as uranine) is Acid Yellow 73; its color index number is 45350. The dye mixture used in the Electric Lake investigations was a powder consisting of approximately 75% dye equivalent and 25% diluent. The powdered dye mixture was mixed with water prior to introduction.

Eosine dye (also known as eosin) is Acid Red 87; its color index number is 45380. The dye mixture used in the Electric Lake investigations was a powder consisting of approximately 75% dye equivalent and 25% diluent. The powdered dye mixture was mixed with water prior to introduction. Throughout this report both fluorescein and eosine dye quantities and dye concentrations are based upon the as-sold weight of the dye mixtures.

Sampling for the presence of fluorescein and eosine dyes is done in two ways. Water samples can be directly analyzed or activated carbon samplers can be utilized. Activated carbon samplers used in this study were fiberglass screen packets that contained 4.25 grams of a laboratory grade of activated coconut shell carbon. The carbon samplers are placed at a sampling station and allowed to remain in place in the water being sampled for a period of time appropriate to the study. The time periods used in this study were commonly about one to two weeks, but shorter or longer periods can be used. The activated carbon adsorbs tracer dyes from the water with which it comes in contact and retains and accumulates the dyes. As a result, because of dye accumulation on activated carbon samplers, the concentration of dye in a carbon sampler is routinely greater than the mean dye concentration in associated water samples.

Water and activated carbon samplers collected in the field were shipped to the Ozark Underground Laboratory (OUL) for analysis. Activated carbon samplers are washed in the laboratory to remove sediment and any plant material that may be present. They are then eluted in a strong base and alcohol solution to desorb the dye from the carbon. The eluting solution is then subjected to analysis in a spectrofluorophotometer operated under a synchronous scan protocol. Water samples are directly analyzed in the same instrument. Appendix A is a copy of the August 22, 2003 OUL dye tracing procedures and criteria document. It provides a detailed discussion of the dye tracing and analysis methods employed during this groundwater tracing investigation.

There is no established EPA or ASTM standard method for dye analysis work associated with groundwater tracing. The methods used by the OUL in this investigation are found in Appendix A. The OUL has a large database from groundwater traces conducted using these protocols. Using this database the OUL has calculated acceptable emission fluorescence wavelengths for fluorescein and eosine in both water and the eluting solution. The acceptable emission wavelength range is based upon the mean emission fluorescence value plus and minus two standard deviations. The OUL has also established detection limits for both dyes in both water and eluting solutions. Acceptable emission fluorescence wavelengths and detection limits are as follows:

Dye	**Matrix**	**Acceptable Emission Wavelength Range (nm)**	**Detection Limit (ppb)**
Fluorescein	Elutant	513.6 to 517.9	0.025
Fluorescein	Water	506.9 to 509.9	0.002
Eosine	Elutant	535.2 to 541.8	0.050
Eosine	Water	532.1 to 540.9	0.015

April 1, 2003 Dye Introductions and Results

Appendix B is an OUL memo dated December 2, 2003 documenting two dye introductions (one with 50 pounds of eosine dye mixture and the other with 35 pounds of fluorescein mixture) made on the floor of Electric Lake on April 1, 2003. At the time of the dye introductions the ice cover was great enough that we were able to walk on top of it. Holes were drilled through the ice and the dye for each location (mixed with water) was introduced through a one-inch diameter pipe to a location approximately six inches above the bottom of the lake. The eosine was introduced at a location overlying the Diagonal Fault, and fluorescein was introduced at a location overlying the Connelsville Fault.

Tracer dyes from the April 1, 2003 dye introductions were detected at a number of sampling stations in Electric Lake, at two sampling stations on Huntington Creek downstream of Electric Lake, and in two wells (JC-1 and JC-3) that penetrate into or near portions of the Skyline Mine located within the Huntington Creek topographic basin. Some fluorescein dye has also been detected at Sampling Station 1 (Eccles Creek 1/4 mile downstream of the Skyline Mine). While it is possible that some of the fluorescein dye detected at Station 1 is derived from our dye introduction, some or all of the detected dye is probably from anti-freeze leakage from equipment used at the mine or anti-freeze fluids leaked from vehicles onto the parking and loading area at the mine or onto the nearby highway.

A substantial amount of dye sampling and analysis work was done within Electric Lake. This work demonstrated and quantified the migration of both of the tracer dyes through essentially all of the lake between the dye introduction points and the dam. Preliminary calculations suggest that about 15 to 20% of the dye introduced on April 1, 2003 discharged through the dam and into Huntington Creek. Other losses of dye due to adsorption, biological degradation, and destruction by sunlight would occur within the lake. Final estimates of the amount of dye that did not enter the groundwater system fault zones have not been made.

Sampling Station 2 was the JC-1 Well. It is completed into a water-saturated fault system intersected by the Skyline Mine. The JC-1 Well intersected the fault system within a horizontal distance of 100 feet from the mine workings. The mine workings adjacent to where JC-1 Well intersects the water-saturated fault system have been flooded since the fault was intersected by the mine workings in August 2001.

Fluorescein dye (and in two cases eosine dye) was detected in three of the five following carbon samplers from the JC-1 Well:

- 5/29 1800 hours to 6/12/03 1115 hours. Fluorescein concentration 0.967 ppb, eosine concentration 0.189 ppb.
- 6/12 1115 hours to 6/18/03 1530 hours. Fluorescein concentration 0.801 ppb. Eosine not detectable.
- 6/18/03 1530 hours to 6/24/03 0745 hours. Well shut down for electrical work; no sample.

- 6/24 0745 hours to 6/30/03 1245 hours. No dyes detected.
- 6/30 1245 hours to 7/7/03 1430 hours. No dyes detected.
- 7/7 1430 hours to 7/14/03 1045 hours. Fluorescein concentration 1.04 ppb, eosine concentration 0.562 ppb.

Prior to the first detection of dye in the JC-1 Well there had been 12 samples in a row (from February 27 to May 29, 2003) in which there was neither fluorescein nor eosine dye. Subsequent to the sampler in place for the period from July 7 to 14, 2003 there were no tracer dyes detected at JC-1 Well through the end of sampling for the April 2003 dye introductions.

The three positive fluorescein peaks at the JC-1 Well are all fully consistent with the presence of this tracer dye. The two eosine dye detections at the JC-1 Well represent fluorescent shoulders on the analytical graph but are fully consistent with the presence of eosine dye in the samples.

The tracer dyes were introduced on April 1, 2003. They were first detected at JC-1 in a carbon sampler in place for the period from May 29 to June 12, 2003. If we use the mid-point of this sampling period as the time of first dye arrival then the time of first dye arrival was 65 days after dye introduction for both of the tracer dyes. The straight-line distance between the dye introduction point and JC-1 was approximately 7,200 feet for the eosine dye and 8,400 feet for the fluorescein dye. Based upon these distances and a first-arrival travel time of 65 days, the mean first dye arrival groundwater velocity was 111 feet per day for the eosine and 129 feet per day for the fluorescein.

Well JC-3 intersects the Skyline Mine workings near where the Skyline Mine intersected the water-saturated fault system. It did not begin pumping water that could be sampled for tracer dye until August 13, 2003. This was after the period in which the tracer dyes were detected at Well JC-1. The first activated carbon sampler from JC-3 (in place for the period from August 13 to August 19, 2003) had a fluorescence peak at 513.4 nm. This is 0.2 nm shorter than the normally acceptable emission wavelength range for fluorescein dye in the eluting solution. The shape of the peak is fully consistent with fluorescein dye, and it is not uncommon for small fluorescein concentrations to display fluorescence peaks a few tenths of a nanometer shorter than the normally acceptable range established for this dye. It is our conclusion that this fluorescence peak does represent fluorescein dye derived from the dye that we introduced into Electric Lake. The fluorescein concentration in this sample was 1.43 ppb.

Bench Test

A bench test was conducted to assess the magnitude of dye losses onto samples of local bedrock. The bench test was designed to determine if it was likely that a significant quantity of dye might have been detained, lost onto, or destroyed by contact with bedrock during the Electric Lake groundwater tracing work. If significant quantities of dye solution were detained or lost, then low or non-detections of dye at sampling points might be attributable to dye losses rather than a lack of large volume hydrologic connection between Electric Lake and the sampling points.

Appendix B (a December 2, 2003 OUL memo) explains the design of the bench test and provides some early results. Appendix C is an August 12, 2004 draft final report on the bench tests.

PacifiCorp provided samples of different rock types that are present along the anticipated groundwater flow path from Electric Lake to the Skyline Mine. The samples are identified in the following table and the relative distance groundwater travels within each rock type as a percentage of the total distance is estimated. The estimates were provided by PacifiCorp.

Rock types and their relative percentage along the anticipated groundwater flow route from Electric Lake to the Skyline Mine.

Lithology	Percentage
Starpoint Sandstone	50%
Fluvial Sandstone	20%
Interbeds	15%
Mudstone	12%
Carbonaceous Mudstone	2%
Coal	1%

The coal sample was from the Skyline Mine load out facility. Samples of the other five rock types were core samples from PacifiCorp's coal mine located to the south of Electric Lake. This mine has the same rock sequence as that in the area of the Skyline Mine. All samples were crushed in a jaws crusher at a local engineering test laboratory to a diameter of less than 1/2 inch; each sample was passed through the crusher twice.

The following is excerpted from the draft final report on the bench test.

1. The bench test used rock cores or other fresh rock from the six geologic units existing between the floor of Electric Lake and the Skyline Mine. Samples of the six geologic substrates were crushed and submerged in 5 and 50 ppb concentrations of fluorescein and eosine dyes. Samples of the dye solutions on top of the rock substrates were periodically collected over a 63 day period and analyzed to determine dye concentrations.

2. The bench test demonstrated that different rock substrates have different abilities to remove dye from dye solutions that are in contact with the rock. Some of the rock substrates are capable of removing the dye very rapidly; this is demonstrated by samples analyzed one day after the dye solutions were placed in contact with the substrates. For all dye solutions the substrate that provide the most rapid dye loss was the Starpoint sandstone. The mudstone was the second most rapid, but the percentages of dye lost to this substrate were substantially less than those lost to the Starpoint sandstone. The two

substrate types which had the least dye lost from the dye solutions after one day were the fluvial sandstone and the carbonaceous mudstone.

3. The bench test was continued for 63 days. For all dye solutions the substrate that provided the greatest dye loss after 63 days was the carbonaceous mudstone. The Starpoint sandstone had the second greatest dye loss after 63 days. Three of the substrates in contact with the 5 ppb eosine solution had no detectable eosine present at Day 63. The two substrate types that had the least dye lost from the dye solutions after 63 days were the coal and the fluvial sandstone.

4. The Starpoint sandstone represents about 50% of the rock mass that would likely be encountered by water traversing the flow route between Electric Lake and Skyline Mine. Fluvial sandstone represents about 20% of the rock mass, interbeds represent 15%, mudstone represents 12%, carbonaceous mudstone represents 2%, and coal represent 1% of the rock mass likely to be encountered by water following this flow route. Using these percentages we calculated weighted averages of dye losses likely to be encountered by waters moving from Electric Lake to the Skyline Mine.

Based upon the weighted averages, at the end of the 63-day bench test the 50 ppb fluorescein dye solutions contained 3.5 times more dye than did the 50 ppb eosine solutions. The 5 ppb fluorescein solutions contained 4.6 times more dye than did the 5 ppb eosine solutions. The percent of dye lost to substrates after 63 days was greater for 5 ppb dye solutions than for 50 ppb solutions. This applied to both fluorescein and eosine solutions, but the percentage difference was greater for eosine than for fluorescein.

5. The bench test demonstrated that appreciable amounts of tracer dyes are lost onto or destroyed by contact with rock substrates found in the area between Electric Lake and the Skyline Mine. In this hydrogeologic environment fluorescein is a much better groundwater tracing agent than is eosine. Because of the appreciable losses of dyes onto rock substrates, the detection of small amounts of dye during field investigations are adequate to demonstrate a hydrologic connection. Furthermore, the detection of only small dye concentrations does not indicate that only small amounts of water follow the traced flow path.

February 24, 2004 Dye Introductions

Two dye introductions were made at Electric Lake on February 24, 2004. The purpose of these dye introductions was to identify points to which water from these locations flows through the groundwater system and to replicate the trace from the April 1, 2003 dye introductions.

The first of the 2004 dye introductions (Trace 04-01) was made at Way Point 26. This location is on the Diagonal Fault, and is about the same location where 50 pounds of eosine dye mixture was introduced near the floor of the lake on April 1, 2003. For Trace 04-01 75 pounds of fluorescein dye mixture containing approximately 75% dye equivalent and 25% diluent was mixed with approximately 75 gallons of water and pumped through a plastic pipe to a location 2 feet above the floor of the lake. The dye introduction began at 1217 hours on February 24, 2004 and was completed at 1223 hours.

The second of the 2004 dye introductions (Trace 04-02) was made at Way Point 16. This location is on the Connelsville Fault, and is about the same location where 35 pounds of fluorescein dye mixture was introduced near the floor of the lake on April 1, 2003. For Trace 04-02 125 pounds of fluorescein dye mixture containing approximately 75% dye equivalent and 25% diluent was mixed with approximately 125 gallons of water and pumped through a plastic pipe to a location 2 feet above the floor of the lake. Dye introduction began at 1447 hours on February 24, 2004 and was completed at 1455 hours.

The dye mixing for both of the dye introductions was done on site in barrels using a trolling motor. Dye was shipped to the site in four containers, each of which contained 50 pounds of the dye mixture. The dye in one of the containers was divided approximately in half on-site so that approximately 75 pounds of dye could be introduced at Way Point 26 and approximately 125 pounds could be introduced at Way Point 16. Prior to beginning field work samples of the dye from each container were analyzed at the OUL to verify that the contents were in fact fluorescein dye.

During the dye introductions there was a light breeze with gusts up to 5 or 10 miles per hour. The fluorescein dye mixture was delivered to the site as a powder, and small amounts of the powder were lost into the air when the containers of dye were added to the mixing barrels. The breeze transported this small amount of dye downwind; the maximum visible extent of the drift was about 250 feet. We estimate that the total amount of dye mixture lost to drift was less than one ounce. This dye would be destroyed by sunlight and would in no way interfere with the conduct of the tracer test.

The mixture of dye and water was denser than water alone. As a result, the dye mixture sank to the bottom of the lake and flowed along the low points on the lake bottom. These conditions were deemed suitable for the purposes of these dye traces.

Fluorescein dye derived from the February 2004 dye introductions has been detected at Stations 2, 10, 11, 120, and 121. These detections are described in the following paragraphs.

Station 2. JC-1 Well. Detections of fluorescein dye from activated carbon samplers placed at JC-1 Well are summarized in Table 1. This dye is from the February 2004 dye introductions in Electric Lake.

It is our conclusion that the first dye detection at this station was in an activated carbon sampler in place for the period from December 28, 2004 to January 20, 2005. The emission fluorescence peak in the elutant from this sampler was at 514.8 nm, and the fluorescein dye concentration was 0.885 parts per billion (ppb). While the shape of this peak was less smooth and symmetrical than fluorescence peaks commonly associated with this concentration of fluorescein dye in eluting solutions, the peak wavelength is within the acceptable wavelength range of fluorescein dye in eluting solutions.

Table 1. Fluorescein dye detections in JC-1 Well from dye introduced in Electric Lake on February 24, 2004. All detections are from activated carbon samplers.

Date Placed	Date Recovered	Peak Wavelength (nm)	Fluorescein Concentration (ppb)
12/28/04	1/20/05	514.8	0.885
1/20/05	2/3/05	513.9	1.33
2/3/05	2/17/05	513.8	0.776
2/17/05	3/3/05	513.8	4.92
3/3/05	3/11/05	513.8	1.94
3//11/05	3/17/05	513.6	0.619
3/17/05	3/22/05	513.8	1.31
3/22/05	4/1/05	514.0	0.805
4/1/05	4/7/05	ND	
4/7/05	4/14/05	513.0*	0.591*
4/14/05	4/28/05	513.2*	0.742*
4/28/05	5/12/05	514.6	0.936
5/12/05	5/26/05	514.7	1.06

* Fluorescence peak is shorter than the normally acceptable wavelength range for this dye. The peak is calculated as fluorescein dye.
ND = None Detected

Fluorescein dye was subsequently detected in activated carbon samplers from JC-1 Well for the next seven sampling periods (see Table 1). These samplers covered the period from January 20 to April 1, 2005. Fluorescein dye was not detected in the activated carbon sampler in place at JC-1 Well for the period from April 1 to April 7, 2005. Samplers in place at JC-1 Well for the periods from April 7 to 14 and from April 14 to April 28, 2005 had fluorescence peaks that were probably reflective of fluorescein dye but which had emission fluorescence peaks somewhat shorter than the acceptable emission wavelength range for fluorescein in eluting solutions. However, fluorescein dye was again detected at this sampling station in the following two samplers covering the period from April 28 to May 26, 2005. Subsequent samplers have not yet been analyzed and added to the data file.

The largest dye concentration at JC-1 was in an activated carbon sampler in place for the period from February 17 to March 3, 2005. The fluorescein concentration in this sampler was 4.92 ppb, and the shape of the fluorescence peak was smooth, symmetrical, and fully consistent with fluorescein dye peaks in the eluting solution. The emission fluorescence peak was at 513.8 nm. The next activated carbon sampler from JC-1 Well was in place for the period from March 3 to 11, 2005. It had an emission fluorescence peak at 513.8 nm and a fluorescein concentration of 1.94 ppb. The shape of the fluorescence peak was less smooth than in the previous sample, but still fully consistent with fluorescein dye peaks of this concentration in eluting solutions.

During the period from December 2, 2003 to December 28, 2004 there were 36 carbon samplers analyzed from JC-1 Well. Twenty-six of these had emission fluorescence peaks ranging from 507.8 to 512.6 nm; this range is appreciably shorter than the acceptable emission fluorescence range for fluorescein (which is 513.6 to 517.9 nm). Most of these peaks were also irregular in shape. As a result of the above, it is our conclusion that fluorescein dye was not detected in these samplers.

We made a further assessment of the presence of fluorescence peaks shorter than fluorescein dye in a number of samples from JC-1 Well prior to the detection of fluorescein dye at this station. The mean emission fluorescence wavelength of these 26 samples was 510.9 nm with a standard deviation of 1.3 nm.

During the period when fluorescein dye has been detected in activated carbon samplers from JC-1 Well there have been a total of 13 samples collected and analyzed. Twelve of these had fluorescence peaks, and ten of these peaks were within the acceptable wavelength range of fluorescein dye. The mean emission fluorescence peak in these twelve samplers was 513.9 nm with a standard deviation of 0.6 nm.

Figure 1 is a graph depicting the emission fluorescence peaks of activated carbon sampler elutants from JC-1 Well for all samplers with fluorescence peaks between 507.8 and 514.8 nm. The plotted dates shown on the graph reflect the dates of sampler collection. Note the substantial increase in the peak emission wavelengths associated with the presence of fluorescein dye (the mean value is 513.9 nm) as contrasted with the peak emission wavelengths associated with samplers collected on or before December 29, 2004 (510.9 nm).

Fluorescein dye was introduced at two locations on the floor of Electric Lake on February 24, 2004. This dye was first detected at JC-1 Well in an activated carbon sampler in place for the period from December 28, 2004 to January 20, 2005. If we use the mid-point of this sampling period as the time of first dye arrival (thus January 8, 2005) then the first dye arrival at this well occurred 318 days after dye introductions made in February 2004.. The straight-line distance from JC-1 Well to the nearest dye introduction point is 7,200 feet thus yielding a minimum straight-line groundwater velocity of 23 feet per day. The maximum dye concentration arrival at JC-1 Well occurred during the period from February 17 to March 3, 2005. Using the mid-point of this period (February 24, 2005) this represented a minimum straight-line groundwater velocity of 20 feet per day.

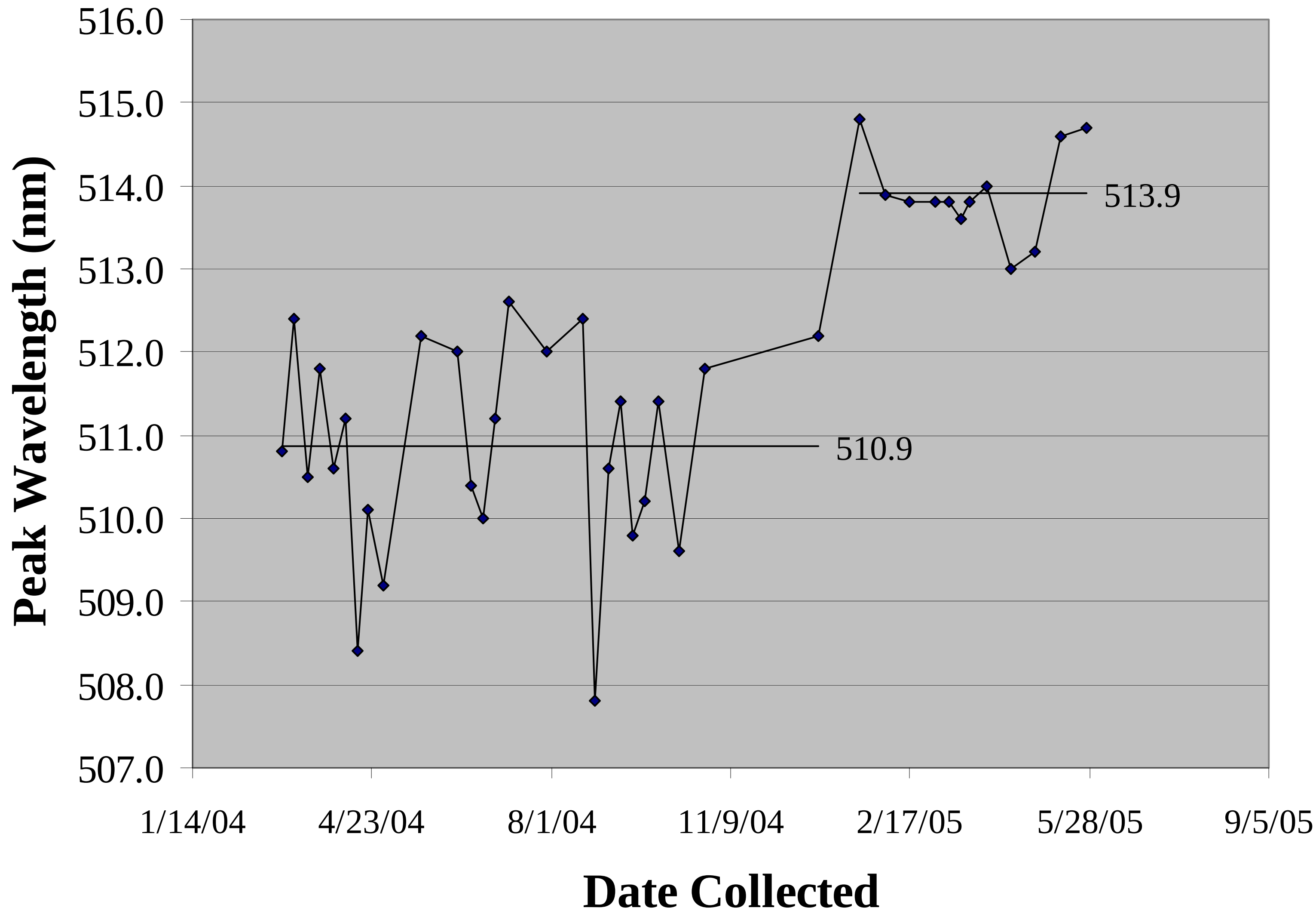
Station 10, Huntington Creek below Dam 1. The first dye detection from the February 2004 dye introduction was probably during the period from March 2 to 11, 2004; the fluorescein concentrations was about 3 times the background concentration. Samplers in place at this station for the period between March 11 and 18, 2004 had 2 orders of magnitude more dye than did background samplers. The peak dye concentration at this station from the present dye trace occurred during the sampling period from March 18 to 25, 2004. Subsequent dye concentrations at this station have generally decreased with time.

Station 11, Huntington Creek below Dam 2. The first dye detection from the February 2004 dye introduction was probably during the period from March 2 to 11, 2004; the fluorescein concentrations was about 2 times the background concentration. Samplers in place at this station for the period between March 11 and 18, 2004 had 2 orders of magnitude more dye than did background samplers. The peak dye concentration at this station from the present dye trace occurred during the sampling period from March 18 to 25, 2004. Subsequent dye concentrations at this station have generally decreased with time.

Stations 120 and 121. Relatively small dye concentrations from the February 2004 dye introduction were detected in activated carbon samplers at Station 120 (Huntington Creek Above Left Fork of Huntington Confluence) and at Station 121 (Huntington Creek at Little Bear Campground). This dye was derived from dye that had flowed past Stations 10 and 11.

Sampling is continuing for this trace and final data analysis is in progress.

Figure 1. Emission fluorescence peaks in activated carbon sampler elutants from JC-1 Well. Horizontal lines represent mean values for the periods shown



Important Information and Findings from the Dye Tracing Investigations.

1. JC-1 Well is completed into a water-saturated fault system intersected by the Skyline Mine. The JC-1 Well intersected the fault system within a horizontal distance of 100 feet of the mine workings. The mine workings adjacent to where the JC-1 Well intersects the water-saturated fault system have been flooded since the fault was intersected by the mine workings in August 2001.

2. Well JC-3 intersects the Skyline Mine workings near where the Skyline Mine intersected the water-saturated fault system. It did not begin pumping water that could be sampled for tracer dye until August 13, 2003. This was after the period in which the tracer dyes were detected at Well JC-1. The first activated carbon sampler from JC-3 had a fluorescence peak at 513.4 nm. This is 0.2 nm shorter than the normally acceptable emission wavelength range for fluorescein dye in the eluting solution. The shape of the peak is fully consistent with fluorescein dye, and it is not uncommon for small fluorescein concentrations to display fluorescence peaks a few tenths of a nanometer shorter than the normally acceptable range established for this dye. It is our conclusion that this fluorescence peak does represent fluorescein dye derived from the dye that we introduced into Electric Lake. The fluorescein concentration in this sample was 1.43 ppb.

3. Thirty-five pounds of fluorescein dye mixture was introduced on the floor of Electric Lake over the Connelsville Fault on April 1, 2003. Fluorescein dye was subsequently detected in JC-1 Well. This dye was detected in three activated carbon samplers from this well. The first dye detection was during the period from May 29 to June 12, 2003. Using the mid-point of this time period as the time of first arrival then the time of first dye arrival was 65 days after dye introduction. The straight-line travel distance from the fluorescein dye introduction point to JC-1 Well is 8,400 feet, and the mean travel rate for the first fluorescein dye arrival is 129 feet per day.

4. Fifty pounds of eosine dye mixture was introduced on the floor of Electric Lake over the Diagonal Fault on April 1, 2003. Eosine dye was subsequently detected in JC-1 Well. This dye was detected in two activated carbon samplers from this well. The first dye detection was during the period from May 29 to June 12, 2003. Using the mid-point of this time period as the time of first arrival then the time of first dye arrival was 65 days after dye introduction. The straight-line travel distance from the fluorescein dye introduction point to JC-1 Well is 7,200 feet, and the mean travel rate for the first eosine dye arrival is 111 feet per day.

5. Well JC-3 (which intersects the Skyline Mine) did not begin pumping water that could be sampled for tracer dye until August 13, 2003. This was after the period in which the tracer dyes were detected at Well JC-1. The first activated carbon sampler from JC-3 (in place for the period from August 13 to August 19, 2003) had a fluorescence peak at 513.4 nm. This is 0.2 nm shorter than the normally acceptable emission wavelength range for fluorescein dye in the eluting solution. The shape of the peak was fully consistent with fluorescein dye, and it is not uncommon for small

fluorescein concentrations to display fluorescence peaks a few tenths of a nanometer shorter than the normally acceptable range established for this dye. It is our conclusion that this fluorescence peak represents fluorescein dye derived from the dye introduced into Electric Lake on April 1, 2003. The fluorescein concentration in this sample was 1.43 ppb.

6. A bench test was conducted to determine if significant quantities of eosine or fluorescein dye might have been detained, lost onto, or destroyed by contact with bedrock during the Electric Lake groundwater tracing work. If significant quantities of dye solution were detained or lost, then low or non-detections of dye at sampling points might be attributable to dye losses rather than a lack of large volume hydrologic connection between Electric Lake and the sampling points.

7. The bench test demonstrated large percentage dye losses from 5 and 50 ppb dye solutions placed in contact with rocks typical of the area. In the test samples 135 grams of crushed rock was covered by 250 ml of dye solution. By weight this is 1.85 times more dyed water than crushed rock. In the bench test much of the dye loss occurred within the first day of contact between the rock and dyed water. However, additional dye loss continues to occur after the first day and, in most cases, throughout the duration of the 63 day study. The discovery of both initial rapid dye losses and continuing dye losses are important. The bench test data demonstrating that the relatively small dye concentrations detected in the Skyline Mine do not indicate that the volume of water moving from the lake into the mine is small.

8. Approximately half of the anticipated groundwater flow route from Electric Lake into the Skyline Mine is through the Starpoint Sandstone. In the bench test this unit removed 89.7% of the fluorescein from a 50 ppb dye solution after one day of contact and 96.0% of the fluorescein after 7 days of contact. The losses were even greater for eosine dye. In the bench test the Starpoint Sandstone removed 96.4% of the eosine from a 50 ppb dye solution after one day of contact and 96.8% after 7 days of contact. Percentage loss rates were even greater for 5 ppb fluorescein and eosine solutions.

9. A second round of dye introductions into the floor of Electric Lake were made on February 24, 2004. Seventy-five pounds of powdered fluorescein dye mixture was mixed with water and introduced on the Diagonal Fault at about the same location where 50 pounds of eosine dye mixture was introduced on April 1, 2003. An additional 125 pounds of powdered fluorescein dye mixture was mixed with water and introduced on the Connelsville Fault at about the same location where 35 pounds of fluorescein dye mixture was introduced on April 1, 2003.

10. Fluorescein dye from the February 24, 2004 dye introduction was first detected at the JC-1 Well in an activated carbon sampler in place for the period from December 28, 2004 to January 20, 2005. The maximum fluorescein dye concentration detected at this station was in an activated carbon sampler in place for the period from February 17 to March 3, 2005. The fluorescein concentration in this sampler was 4.92 ppb, and the shape of the fluorescence peak was smooth, symmetrical, and fully

consistent with fluorescein dye peaks in the eluting solution. The emission fluorescence peak was at 513.8 nm. The next activated carbon sampler from JC-1 Well was in place for the period from March 3 to 11, 2005. It had an emission fluorescence peak at 513.8 nm and a fluorescein concentration of 1.94 ppb. The shape of the fluorescence peak was less smooth than in the previous sample, but still fully consistent with fluorescein dye peaks of this concentration in eluting solutions.

11. Fluorescein dye has been detected in most of the activated carbon samplers in place at JC-1 Well for the period December 28, 2004 to June 26, 2005. If we use the mid-point of the first dye detection sampling period as the time of first dye arrival (thus January 8, 2005) then the first dye arrival at this well occurred 318 days after the dye introductions made on February 2004. The straight-line distance from JC-1 Well to the nearest dye introduction point is 7,200 feet thus yielding a minimum straight-line groundwater velocity of 23 feet per day.

12. Groundwater velocities determined from the dye tracing were more rapid during the first tracing period than during the second. It is our understanding that water level elevations in those portions of the Skyline Mine near JC-1 Well were higher during the second tracing period than during the first, and that pumping rates from the vicinity of JC-1 Well and the adjacent mine (including JC-3 Well) were less during the second tracing period than during the first. These differences could account for the differences in calculated groundwater velocities between the two study periods.

13. The work summarized in this report demonstrates that Electric Lake loses water into the Skyline Mine. The bench test work demonstrates that dye concentrations in water pumped from the mine or areas near the mine cannot be used to estimate the volume of water lost from the lake into the mine.

References

Aley, Thomas. 2002. The Ozark Underground Laboratory's Groundwater Tracing Handbook. Protem, MO. 35p.

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